The room where most students will take the test for your class, i.e. LS A-191 for on-ground and PS H-152 for hybrid.

**YOU ARE NOT ALLOWED TO TAKE SPARE COPIES OF THIS EXAM FROM THE TESTING ROOM**

<table>
<thead>
<tr>
<th>Elements</th>
<th>Interaction Energies, kcal/mol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eclipsing</td>
</tr>
<tr>
<td>H/H</td>
<td>~1.0</td>
</tr>
<tr>
<td>H/Me</td>
<td>~1.4</td>
</tr>
<tr>
<td>Me/Me</td>
<td>~2.6</td>
</tr>
<tr>
<td>Et/Me</td>
<td>~0.95</td>
</tr>
<tr>
<td>i-Pr/Me</td>
<td>~1.1</td>
</tr>
<tr>
<td>t-Bu/Me</td>
<td>~2.7</td>
</tr>
</tbody>
</table>

**Infrared Correlation Chart**

<table>
<thead>
<tr>
<th>Frequency (cm⁻¹)</th>
<th>NMR Correlation Charts</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000-3100</td>
<td>Aromatic Ar-H</td>
</tr>
<tr>
<td>2850-2960</td>
<td>broad ~3300</td>
</tr>
<tr>
<td>2200</td>
<td>broad ~3000</td>
</tr>
<tr>
<td>1710-1735</td>
<td>1600-1660</td>
</tr>
<tr>
<td>1650</td>
<td>1600-1660</td>
</tr>
<tr>
<td>1680</td>
<td>1600-1500</td>
</tr>
</tbody>
</table>

**NMR Correlation Charts**

<table>
<thead>
<tr>
<th>δ (ppm)</th>
<th>R-CH2-</th>
<th>O-C=CH2</th>
<th>O-C=CH3</th>
<th>O-C-R2</th>
<th>O-C-NR2</th>
<th>O-C-NR3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
<td>4.0</td>
<td>4.5</td>
<td>3.5</td>
<td>3.3</td>
<td>3.2</td>
<td>3.1</td>
</tr>
<tr>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
<td>1.5</td>
<td>1.6</td>
<td>1.7</td>
<td>1.8</td>
</tr>
<tr>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>2.0</td>
<td>2.1</td>
<td>2.2</td>
<td>2.3</td>
<td>2.4</td>
<td>2.5</td>
<td>2.6</td>
</tr>
</tbody>
</table>

**Chemical Elements**

- Li Be B C N O F Ne
- Na Mg Al Si P S Cl Ar
- K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
- Rb Sr Y Er Nb Mo Ru Rh Pd Ag Cd In Sn Sb Te I Xe
- Cs Ba Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn

The range where most students will take the test for your class, i.e. LS A-191 for on-ground and PS H-152 for hybrid.
YOU MUST COMPLETE THIS PAGE WITH YOUR NAME
(EVEN THOUGH YOU ALREADY DID THIS ON THE COVER PAGE)
AND ALSO GIVE YOUR ASU OR POSTING ID NUMBER
WE NEED THIS NUMBER BECAUSE YOU WOULDN'T BELIEVE THE NUMBER OF
STUDENTS WHOSE NAMES WE CAN'T READ!

Points by question
1___________/13
2___________/24
3___________/20
4___________/42
5___________/24
6___________/18
7___________/18
8___________/70
9___________/40
10___________/8
11___________/22
12___________/18
13___________/34
14___________/24

Points Removed for cover errors ___/2

Extra Credit ____/5

Total (incl Extra) ______/175+5

"YOU ARE NOT ALLOWED TO TAKE SPARE COPIES OF THIS EXAM FROM THE TESTING ROOM"
Question 1 (13 pts.) Give the IUPAC name for the following structure. Specify stereochemistry as appropriate.

Question 3 (20 pts.)
a) Draw a picture of the wavefunction, OR the wavefunction squared AS REQUESTED, of the molecular orbitals requested, on the molecules. In each case indicate the A.O.'s used to make the M.O.'s.

Ψ² for the C–C σ orbital
Ψ for the C-Br σ* orbital

Extra Credit (5 pts.) The hole in the ozone layer has been attributed to the atmospheric chemistry of which kind of molecule?

halides alkanes alkanes alcohols
Question 5 (24 pts.) For the following Bronsted acid/base reaction (not all H atoms are included in the provided structures)

a) Draw the curved-arrows that describes the bond making and breaking in BOTH directions
b) Label the STRONGER acid/base and the WEAKER acid/base on EACH side
c) Indicate which reaction would be faster, left to right or right to left
d) Indicate on which side the equilibrium will lie
e) Indicate which acid has the smaller and which the larger pKa
f) Give a BRIEF explanation for your choice of stronger/weaker Bronsted acids/bases that includes drawings of ALL relevant resonance contributors

\[
\begin{align*}
\text{O} & \quad \text{H} \\
\text{H} & \quad \text{O} \\
\end{align*}
\]
Question 6 (18 pts.) For each reaction, decide whether the mechanism would be SN1/SN2/E1 or E2 and give a brief explanation. Draw the product and show stereochemistry where appropriate and state whether a solution of the product would be optically active or not AND give a BRIEF explanation.

a) 

```
       
       
       
       
       
```

1 Equiv. Na⁺ -OEt⁺

acetone
Question 8 (70 pts.) Give the missing major ORGANIC PRODUCT for each reaction
a) Show all stereochemistry as appropriate, identify any MESO compounds
b) Briefly explain whether and why a solution of the product would be optically active or not
c) Assign each reaction as addition, elimination, substitution or rearrangement

a) 

\[
\begin{align*}
\text{Br}_2 & \quad \text{CCl}_4 \\
\end{align*}
\]

b) 

\[
\begin{align*}
\text{Excess HBr} & \quad \text{HOOH} \\
\end{align*}
\]

c) 

\[
\begin{align*}
\text{1. Hg(OAc)}_2/\text{H}_2\text{O} & \quad \text{2. NaBH}_4 \\
\end{align*}
\]

d) 

\[
\begin{align*}
\text{NBS} & \quad \text{hv} \\
\end{align*}
\]

e) 

\[
\begin{align*}
\text{H}_2/\text{Pd/C} \\
\end{align*}
\]

f) 

\[
\begin{align*}
\text{EtOH} & \quad \text{heat} \\
\end{align*}
\]
Question 9 (40 pts.) For each of the following two reactions:

a) Give a curved arrow mechanism, indicate the Lewis acid and Lewis base (LA or LB) for each INTERMOLECULAR step, and whether they are also Bronsted acids and bases (BA or BB).

b) State whether you would expect the reaction to be exothermic or endothermic and give a brief (1 sentence) explanation for your choice.

\[ \begin{align*}
\text{a)} & \quad \text{HBr} & \quad \text{Br} \\
\text{b)} & \quad \text{HCl (cat.)} & \quad \text{Br}
\end{align*} \]

Question 10 (8 pts.) The t-butoxide anion (t-BuO\(^-\)) is a strong base but a weak nucleophile. Give a brief 1 sentence explanation for this.
Question 11 (22 pts.)

a) Give the product of the following Lewis acid/base reaction, indicate the Lewis acid and base (LA/LB) and if they are also Bronsted acids bases (BA/BB).

b) Draw a reaction energy diagram for the reaction with properly labelled axes, draw the transition state and indicate its position on the diagram.

c) BRIEFLY explain why your reaction is exothermic or why it is endothermic

\[
\text{H}_2\text{C} = \text{CH}_2 + \text{Na}^+ \text{O}^- \rightarrow \text{Product}
\]

Question 12 (18 pts)

a) Indicate which of the following two structures is the stronger Bronsted base, and give a brief explanation for your choice.

\[
\text{MeO}^- \quad \text{MeS}^-
\]

b) Indicate which of the following two structures A or B is the stronger Bronsted base, and give a brief explanation for your choice.

\[
\begin{array}{c}
\text{A} \\
\text{B Me-C≡N}^{-}
\end{array}
\]
Question 13 (34 pts.)

a) Give a full curved arrow mechanism, indicate the Lewis and Bronsted acids and bases at each step as appropriate. **Give the number of sets of intermediates that are included in your mechanism and also how many transition states are associated with your mechanism.** (This may not be the only product of this reaction, but you need to show the mechanism for formation of THIS product)

\[
\begin{align*}
\text{Br}^- \quad \text{MeOH} & \quad \text{heat} \\
\text{product} \quad & \quad \text{product}
\end{align*}
\]

# of sets of intermediates = 
# of transition states =

b) Draw a reaction energy diagram for the mechanism you drew, do not draw them but indicate the locations of each of the sets of intermediates and the transition states on your diagram. Indicate also the activation energy for the rate determining step and also the reaction exothermicity.
a) Give the degrees of unsaturation ________________

b) On the infrared spectrum, indicate the peaks that identify the functional groups in the molecule (including C(sp³)-H). Indicate **BOTH the functional group**, and where appropriate, **the specific BOND** in the functional that corresponds to the peak.

![Infrared Spectrum Image]

**Wavenumbers**
- 3321
- 2903
- 2981
- 2846
- 1436
- 1356
- 1189
- 958
- 877
- 958

**Peaks and Functional Groups**
- 2903: C-H stretching
- 1436: C-C stretching
- 1189: C-O stretching
- 958: C-H deformation

---

c) draw the structure and clearly indicate which hydrogens correspond to which signals in the proton nmr spectrum (only)

![Proton NMR Spectrum Image]

**Chemical Shifts**
- 6H singlet
- 2H sextet
- 3H triplet
- 2H triplet
- 1H singlet

**Integration**
- 6H singlet
- 2H sextet
- 3H triplet
- 2H triplet
- 1H singlet